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HORIZONTAL GAS ENGINES

LARGE SIZE

Horizontal Gas Engines

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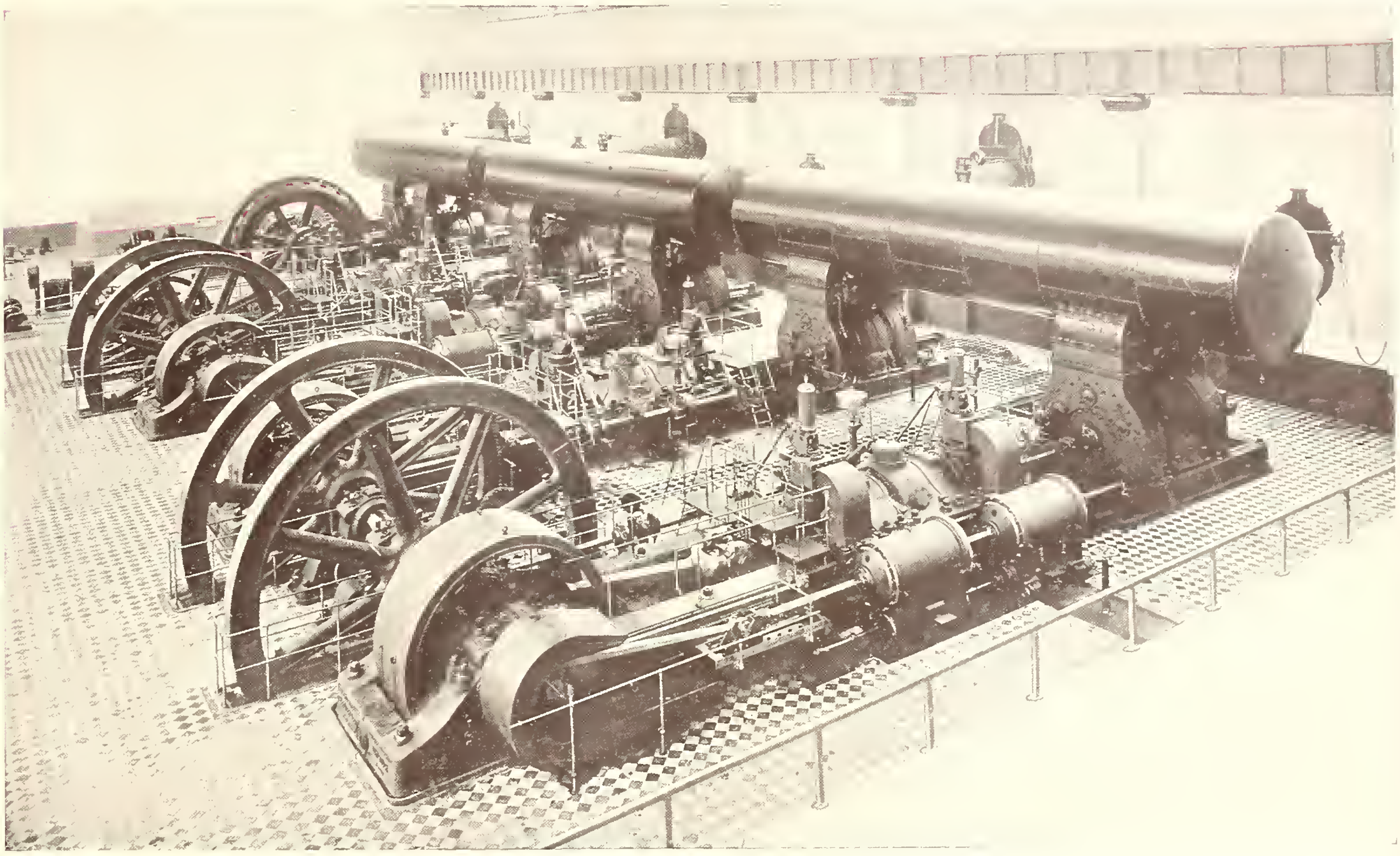

A Typical Two-stroke Cycle Gas Engine Installation
Operating Blowing Engines

VACUUM OIL COMPANY

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FIRST PRINTING

HORIZONTAL GAS ENGINES

LARGE SIZE

Classification; Field of Service; Construction and Principle of Operation; Cooling; Gas; Methods of Lubrication; Oil; Deposits.

CLASSIFICATION

Large Horizontal Gas Engines may be classified as follows:

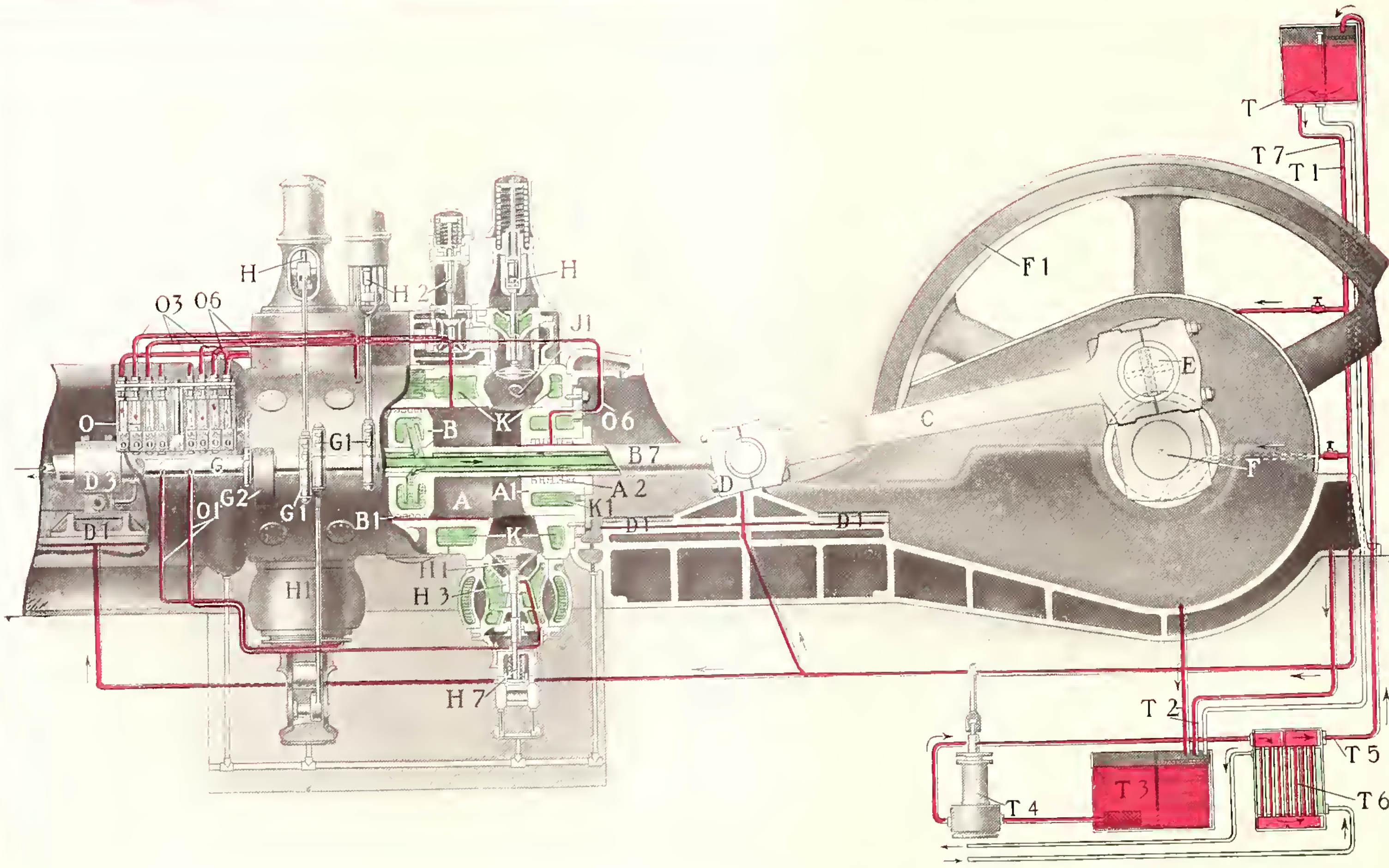
Type	*No. of Cylinders*	*H.P. per Cylinder*	*Revolutions per Minute*
Four-stroke cycle Double acting	One to Four	300 to 1500	150—90
Two-stroke cycle Double acting	One	400 to 2000	90—60

Most large gas engines are of the four-stroke cycle type.

FIELD OF SERVICE

Large gas engines are used for driving large electric generators in iron and steel works, in large collieries, occasionally in large central power stations and, in rare instances, in textile mills. The electric generators produce current for the operation of electric motors, which are used for a variety of purposes throughout the mills.

Large gas engines, usually of the two-stroke cycle type, are also extensively used in steel works to drive blowing engines which produce compressed air for the blast furnaces; a typical installation is illustrated on the title page.



* Fig. 1. Sectional View of One Cylinder of a Tandem, Four-stroke Cycle, Double Acting Gas Engine

FOUR-STROKE CYCLE GAS ENGINES

All large gas engines are double acting, which means that explosions take place on both sides of the piston. For this reason the piston is not an open, hollow, trunk piston, as in the case of small and medium sized gas engines, but is entirely enclosed, and the cylinder in which it operates has covers or heads, at both ends.

Large four-stroke cycle gas engines are rarely built with one cylinder only; they generally have two cylinders, placed one behind the other—called a tandem engine.

The largest of these power units consists of two tandem engines placed side by side—a twin tandem engine—operating an electric generator mounted on the main shaft.

Construction (Fig. 1)

In the cylinder (A) is the piston (B) fitted with piston rings (B1).

The piston rings (B1) are held in position in their grooves and prevented from revolving by means of pegs or pins (not shown), placed in different positions for the different rings, so that the joints of the rings cannot work into line and allow the gases to blow past them.

The piston (B) is fixed on the piston rod (B7) which passes through the cylinder heads (A1) at each end of the cylinder (A). The piston weight is carried by the external supports, *i. e.*, the cross-head (D) and piston rod support (D3), which slide horizontally on their guides (D1).

In order to prevent leakage of the gases, stuffing boxes (A2) are fitted to the piston rods and are located in the cylinder heads (A1) at either end of the cylinder (A).

Gas and air are admitted through the mixing valves (H2) and inlet valves (H), the burned gases leaving the cylinder through the exhaust valves (H1). The exhaust valve spindles (H7) move vertically in their sleeves (H3).

* In this and all following illustrations red indicates oil, blue indicates air, green indicates water and yellow indicates gas.

The explosion forces acting on the piston (B) are transmitted by the piston rod to the cross-head (D). A connecting rod (C) is attached to the cross-head (D) at one end, the other end engaging the crank-pin (E).

The horizontal straight-line movement of the piston (B) is thus transformed, by the connecting rod (C), into rotary motion of the main shaft (F).

On the main shaft (F), which is supported by main bearings (not shown), is fixed the fly-wheel (F1).

The cylinder (A) is fitted with a water-jacket (K) and the cylinder heads (A1) are hollow for cooling purposes, cooling water passing through the cavities (K1). The piston (B) is hollow, as well as the piston rod (B7) through which cooling water enters the piston and returns.

A timing shaft (G), geared to turn at half the engine speed, is shown in front of the engine. Eccentrics (G1)on the shaft operate the levers for actuating the mixing valves (H2), inlet valves (H) and exhaust valves (H1). From the timing shaft is also operated the magneto (not shown) which supplies electric current for the ignition of the fuel charges inside the cylinder (A) by producing a spark at the spark plug at the proper instant. One of the spark plugs (J1) is shown in the inlet chamber below inlet valve (H).

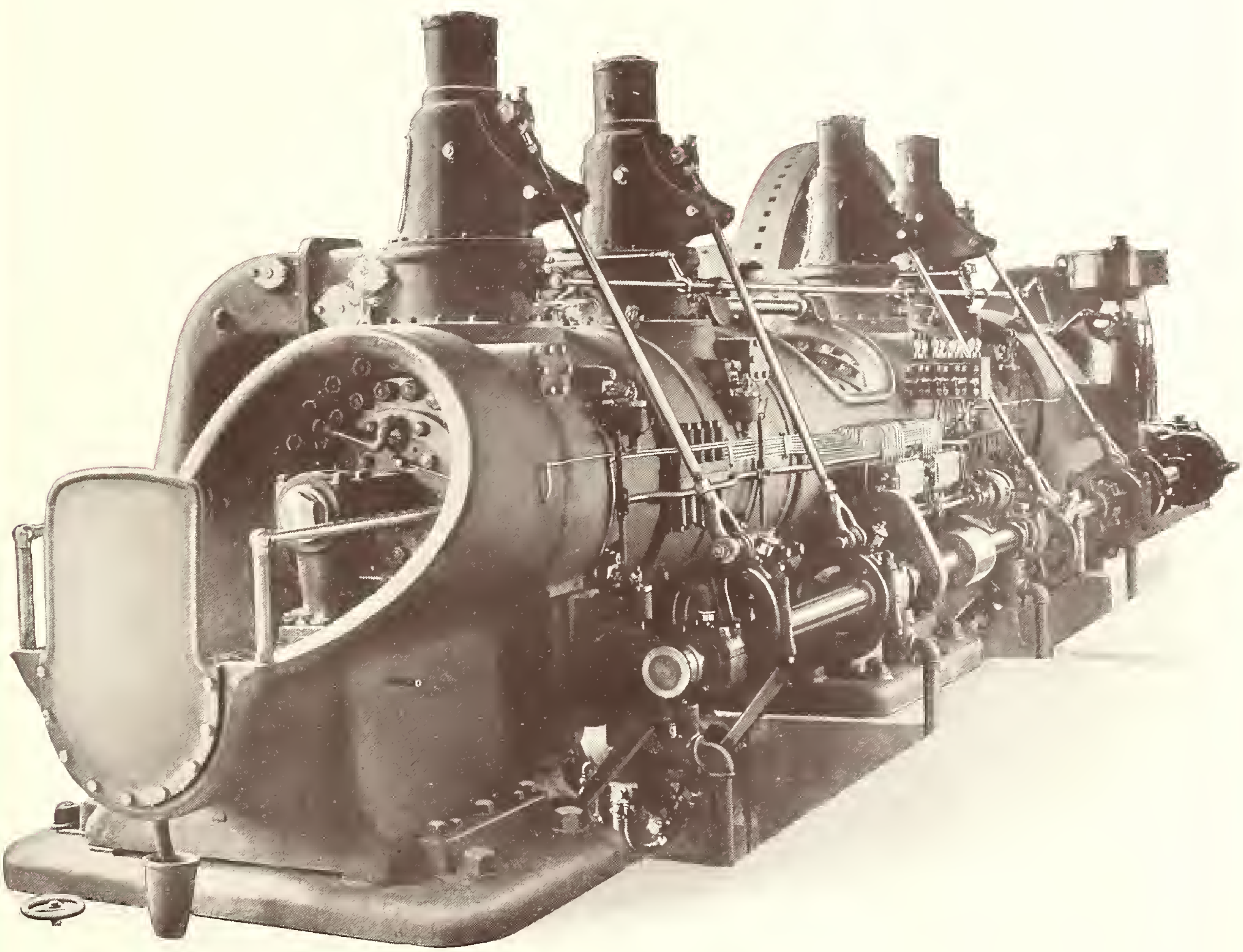
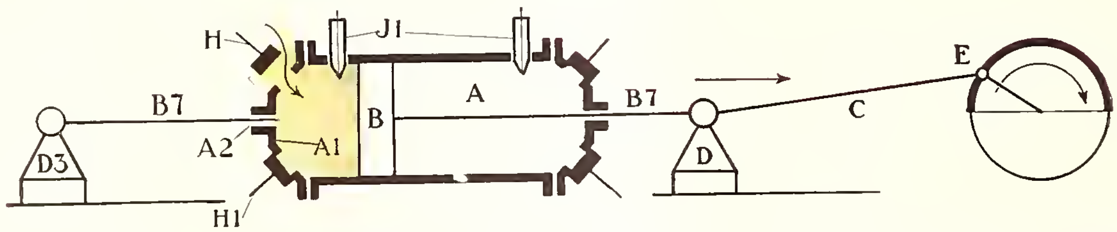


Fig. 2. A Typical Tandem, Four-stroke Cycle, Double Acting Gas Engine Installation

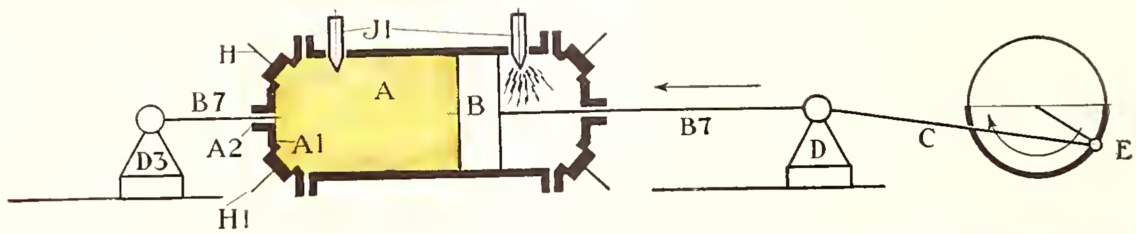
Principle of Operation (Fig. 3)

We will first consider the cycle of events that occurs on the left-hand side of the piston. The principle of operation is as follows:



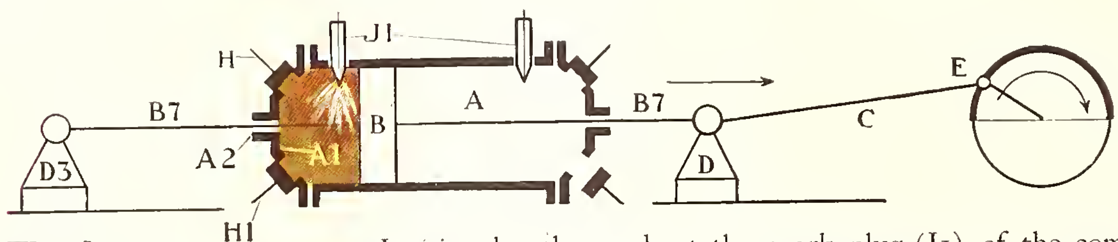
First or Suction Stroke

Gas and air constituting the fuel charge are sucked into the cylinder (A) through the open inlet valve (H) as the piston (B) moves to the *right*. The exhaust valve (H1) is closed.



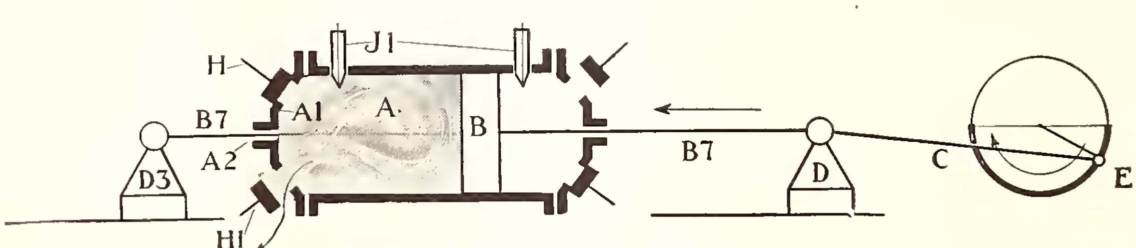
Second or Compression Stroke

The piston (B) moving to the *left* compresses the fuel charge in the cylinder (A). Both inlet and exhaust valves (H) and (H1) respectively are closed.



Third or Power Stroke

Ignition, by the spark at the spark plug (J1), of the compressed fuel charge produces explosion and expansion of the gases, forcing the piston to the *right*. Both inlet and exhaust valves (H) and (H1) respectively are closed.



Fourth or Exhaust Stroke

The piston (B), moving to the *left*, drives the burned gases out through the open exhaust valve (H1). The inlet valve (H) is closed.

During *four strokes of the piston* the flywheel makes *two revolutions*.

The four strokes of the piston, *i. e.*, one power stroke followed by three idle strokes, complete the cycle of events on the left-hand side of the piston: hence the expression four-stroke cycle.

During the complete cycle of events, just described, on the left-hand side of the piston, a similar cycle of events is taking place on the right-hand side of the piston, each event of the cycle, however, occurring one stroke later, as illustrated in the following Table I:

TABLE I

Left Hand	*Right Hand*
Exhaust	Suction
Suction	Compression
Compression	Power
Power	Exhaust

It is obvious that *two power strokes* take place during the *two revolutions* of the flywheel of a *single-cylinder*, four-stroke cycle, double acting gas engine.

In a large tandem (two-cylinder) gas engine the cycle of events occurring on each side of each piston are shown in Table II in the next column.

By reading *down* the columns, it will be observed that a complete cycle of events occurs on each side of each piston, in their proper order.

TABLE II

Cylinder 1		*Cylinder 2*	
Left Hand	*Right Hand*	*Left Hand*	*Right Hand*
Exhaust	Suction	Comp.	Power
Suction	Comp.	Power	Exhaust
Comp.	Power	Exhaust	Suction
Power	Exhaust	Suction	Comp.

By reading *across* the table, it will be observed that at any given position of the pistons the four events comprising a complete cycle are being performed.

It is obvious that *two power strokes* occur *every revolution* of the flywheel of a *tandem (two-cylinder)*, four-stroke cycle, double acting gas engine.

From the foregoing it is evident that *four power strokes* occur *every revolution* of the flywheel of a *twin tandem (four-cylinder)*, four-stroke cycle, double acting gas engine.

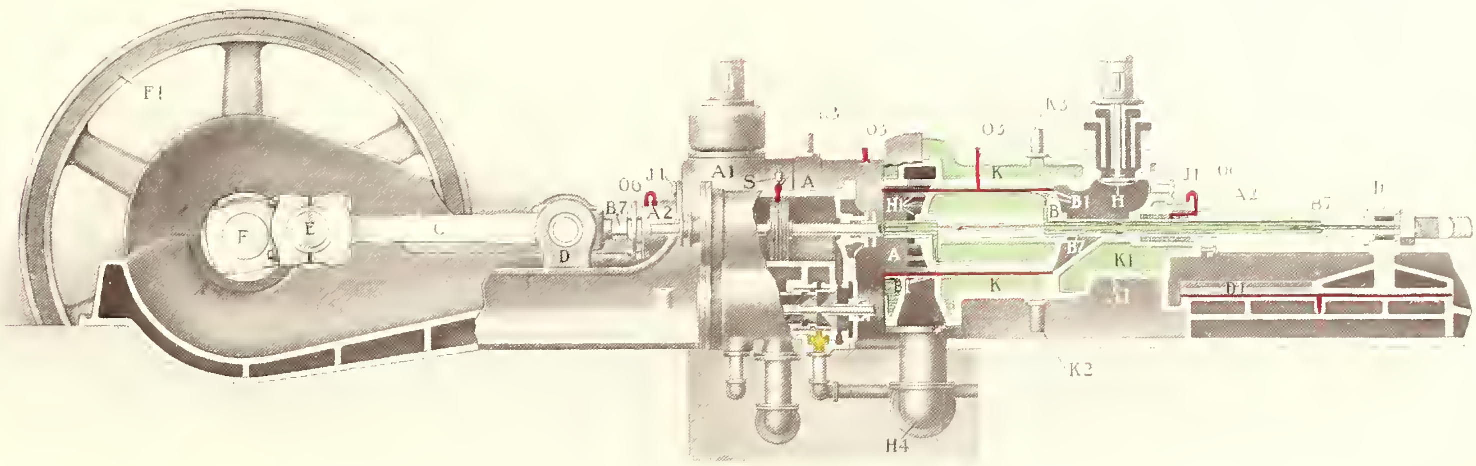


Fig. 4. Sectional View of a Single-cylinder, Two-stroke Cycle, Double Acting Gas Engine, Used for Driving a Blowing Cylinder, as Shown in Installation on the Title Page

TWO-STROKE CYCLE GAS ENGINES

Large two-stroke cycle gas engines are made with only one cylinder, and operate at a lower speed than four-stroke cycle engines.

They are more suitable for the operation of blowing engines as they occupy less space while furnishing a more regular power effort, *i.e.*, a power stroke at each stroke of the piston.

Construction (Fig. 4)

In the cylinder (A) is the piston (B) fitted with pegged piston rings (B1). The piston (B) is fixed on the piston rod (B7) which passes through the stuffing boxes (A2) in the cylinder heads (A1) at each end of the cylinder (A).

The gas and air are admitted through the inlet valves (H), the exhaust gases leaving the cylinder at the center through the exhaust ports (H1) in the cylinder wall (A).

The piston slides on the bottom portion of the cylinder (A) being partly supported by the cross-head (D) and the tail-rod support (D3).

The cylinder (A) is fitted with a water-jacket (K). The cylinder heads are hollow for cooling purposes, cooling water passing through the cavities (K1). The piston (B) is hollow, as well as the piston rod (B7) through which the cooling water enters the piston and returns.

On one side of the engine (see installation on the title page) is shown a timing shaft which turns at the same speed as the engine. On this shaft are fitted eccentrics for operating the levers that actuate the inlet valves. From the timing shaft is also operated the magneto (not shown) which supplies electric current for the ignition of the fuel charge inside the cylinder (A) by producing a spark at the spark plug (J1) at the proper instant.

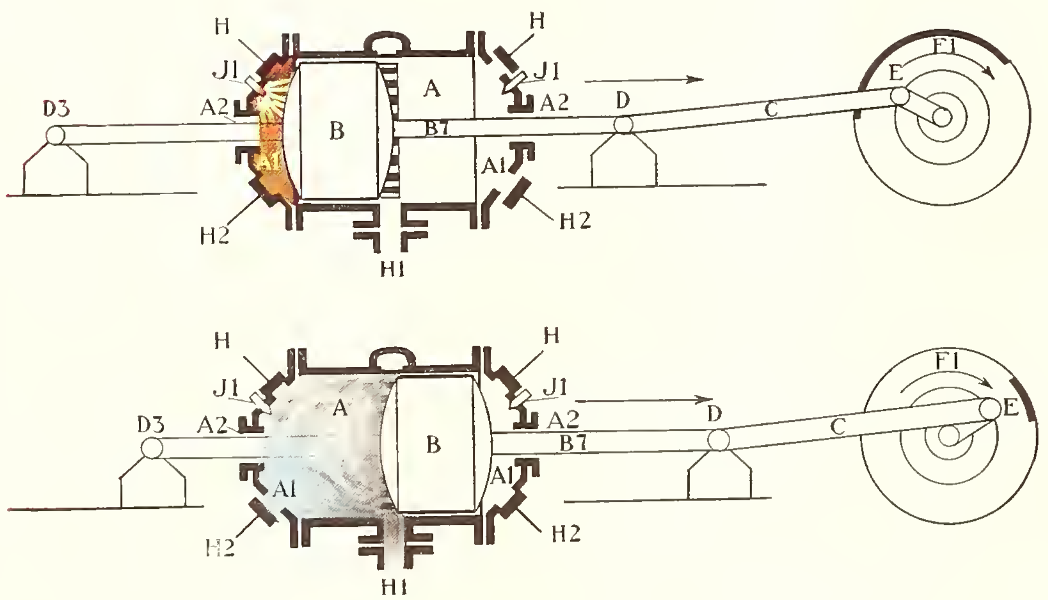
Gas and air are introduced into the engine, under pressure, by means of the gas and air pumps. These pumps are placed horizontally, in tandem formation, beside the power cylinder and are operated from the main shaft by a crank and connecting rod.

These pumps are not water cooled.

Principle of Operation (Fig. 5)

We will first consider the cycle of events that occurs on the left-hand side of the piston.

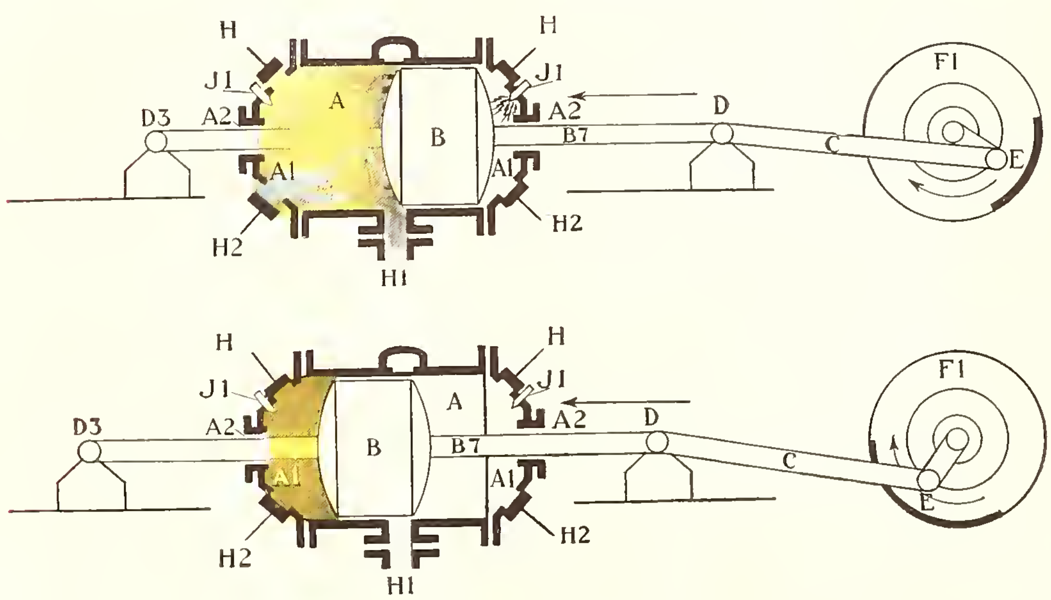
The principle of operation is as follows:



First or Power Stroke

Ignition, by the spark at the spark plug (J1), of the compressed fuel charge, produces explosion and expansion of the gases, forcing the piston (B) to the *right*. The valves (H and H2) are closed.

Just before the end of the stroke, the piston (B) uncovers the exhaust ports (H1). The burned gases escape and at the same instant scavenging air is introduced through the air valve (H2) to assist in driving out the burned gases.



Second or Compression Stroke

At the beginning of the piston stroke to the *left*, air through the air valve (H2) and gas through the inlet valve (H) are introduced into the cylinder, under pressure, from the air and gas pumps respectively. The cylinder is thus filled with a mixture of air and gas. The valves are then closed.

The piston (B), continuing its movement to the left, compresses the fuel charge in the cylinder (A) preparatory to ignition.

Thus the two strokes of the piston, *i. e.*, one power stroke followed by one idle stroke, complete the cycle of events on the left-hand side of the piston; hence the expression two-stroke cycle. From the foregoing it is obvious that the flywheel makes one revolution to every explosion on the left-hand side of the piston.

During the complete cycle of events, just described, on the left-hand side of the piston, a similar cycle of events is taking place on the right-hand side of the piston. Each event in the cycle, however, occurs one stroke later than the corresponding event in the cycle on the left-hand side of the piston, as illustrated in the following table:

Left Hand	*Right Hand*
Power and Exhaust	Intake and Comp.
Intake and Comp.	Power and Exhaust

There is, consequently, one power stroke as the piston (B) moves to the *right* and another power stroke as it returns to the *left*. It is obvious that *two power strokes* occur *every revolution* of the flywheel of a two-stroke cycle, double acting gas engine.

COOLING

It is necessary to cool efficiently all parts which come in contact with the hot gases, namely, the cylinder walls (A), piston (B), piston rods (B7), cylinder covers (A1) and exhaust valve spindles (H7), (Figs. 1 and 4).

Unequal expansion and distortion of the overheated parts, excessive wear and piston seizure would occur without proper cooling.

In large gas engines a temperature of about 2,000° F. is developed at the instant of explosion of the gases in the cylinder. As the gases expand the temperature decreases. The temperature of the exhaust gases average about 750° F

The cooling water is circulated through water spaces by means of circulating pumps. After it returns from the various parts it may be pumped through a cooling tower, cooled, and again used.

Provision is made for adjusting the supply of cooling water to the various parts enumerated above. The temperature of the water from each part can thus be controlled.

If the temperature of the outlet water from the water-jacket is much above 130° F. the cooling of the cylinder walls becomes deficient. The temperature rises, the oil film is thinned out, losing its sealing power, and the exploding gases blow past the piston.

If the temperature of the outlet water is much below 100° F. the cooling of the cylinder walls is over-efficient. The oil film becomes sluggish, the oil spreads with difficulty, and a great deal of power is lost in overcoming the oil drag on the piston.

The average temperature of the cooling water leaving the engine should be between 100° and 130° F.

A temperature of about 115° F. is preferable in order to insure good piston seal and a free sliding motion of the piston—in short, the highest degree of operating efficiency.

Where the gas contains sulphur from coke oven gas, successful results have been obtained by allowing the cooling water to run through the engine at a higher temperature—as high as 160° F. The higher temperature of the cooling water minimizes, or entirely prevents, the condensation of moisture from the expanding gases, and thereby the formation of sulphurous acid, which would attack the internal surfaces of the engine that come in contact with the gases.

As a result of cooling, the average temperature of the cylinder walls is from 200° F. to 250° F., and this moderate temperature makes efficient lubrication possible.

GAS

Large gas engines are operated by one of the following kinds of gas: blast furnace gas, coke oven gas and, occasionally, pressure producer gas.

In case of a shortage in the supply of blast furnace gas in large steel works, the gas supply is frequently supplemented with pressure producer gas, made from coke, which gas is ordinarily used for smelting purposes.

The more the given mixture of gas and air is compressed on the compression stroke, the greater will be the power developed when the mixture is ignited.

When using rich, highly inflammable gas, the compression pressure must be proportionately low; otherwise preignition will occur, due to the heat developed by compression.

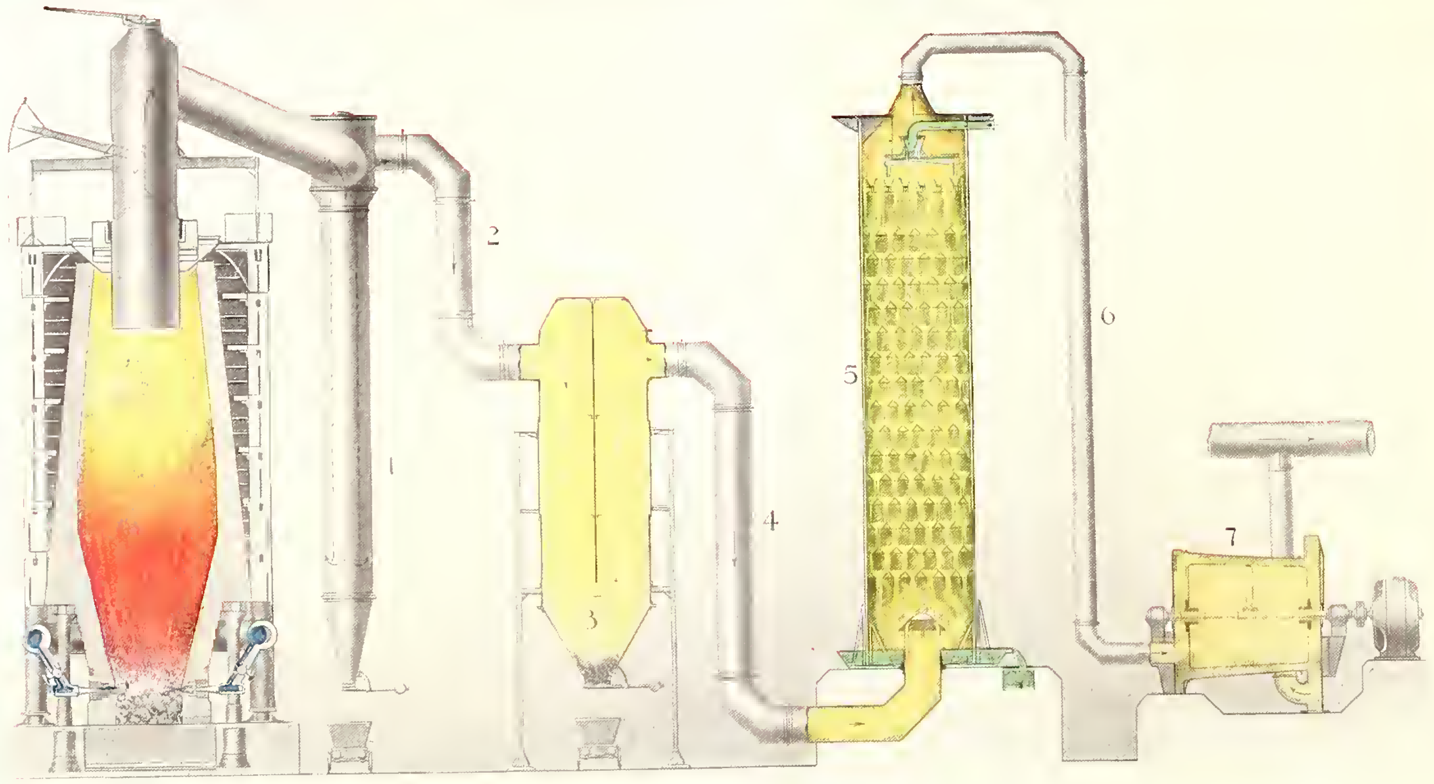


Fig. 6. Blast Furnace Gas Plant

With weak, less inflammable gas, such as blast furnace gas, the compression pressure at the end of the compression stroke can be made much higher.

This is shown in the following table which gives average comparative heat value of gases in British Thermal Units (B. T. U.) and working compression pressure in pounds per square inch:

Kind of Gas	*Heat Value B. T. U.*	*Compression Pressures, lbs. per sq. in.*
Coke Oven	520	130
Pressure Producer	140	160
Blast Furnace	100	190

Blast Furnace Gas (Fig. 6)

The blast furnace gas coming from the blast furnace contains a great quantity of impurities, consisting of lime dust, fine iron oxide, volatile matter and soot from incomplete combustion in the blast furnace, water impurities from the water used in washing the gas, and a small amount of sulphur. The quantity of impurities varies from 12 to 25 grammes per cubic meter of gas, and is reduced in the cleaning plant to .01 to .03 gr. pr. cu. m. If the impurities are more than .05 gr. pr. cu. m. the gas is dangerous for the engines and will cause deposits and excessive wear of piston rings and cylinder walls.

After leaving the dust trap (1), the gas passes through the pipe (2) to a larger dust trap (3), continuing through pipe (4) to the scrubber (5). A water spray coming from the top of the scrubber (5) cools and purifies the rising gas. Through pipe (6) the gas goes to a rotary washing plant (7) which removes nearly all the solid impurities remaining in the gas. This is called the wet filtration process.

Another method, called the dry filtration process, is also in use. By this process it is possible to clean the gas without adding moisture.

From the cleaning plant the gas is conveyed through large gas mains to the gas-engine power house.

Coke Oven Gas

Coke oven gas is produced from bituminous coal during the production of coke. A portion of the gas is used in the coke oven, but the surplus gas can be used for operating gas engines.

Coke oven gas contains, besides coke dust, tar and sulphur, and, consequently, must be cleaned in the same way as gas produced in a pressure producer gas plant using bituminous coal.

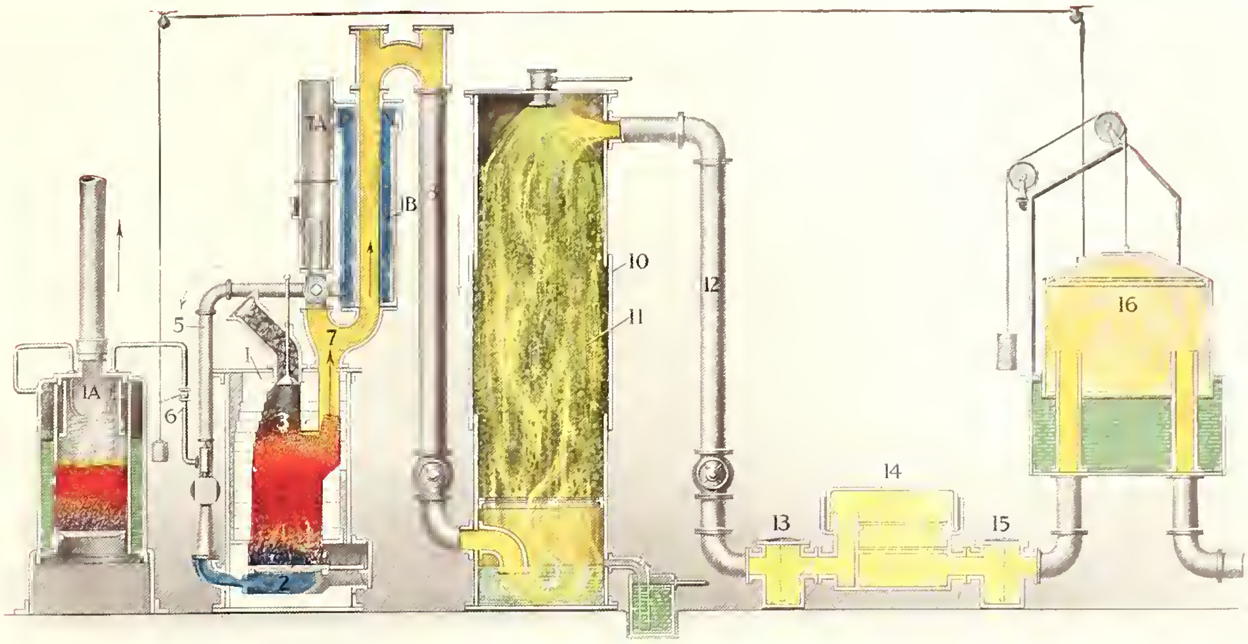


Fig. 7. Illustration of a Typical Pressure Producer Gas Plant

Pressure Producer Gas (Fig. 7)

Pressure producer gas as used for large gas engines is made from bituminous coal, lignite, coke of various kinds, or charcoal.

When bituminous coal or lignite is used, the gas contains tar, soot and sulphur.

When coke or charcoal is used, the gas contains coke dust, but no sulphur.

The gas is produced under a slight pressure, hence the name Pressure Producer Gas.

Where the pressure producer gas plant supplies gas for an installation of 2,000 H.P. or more, a by-product plant for the treatment of tar is frequently installed. Sulphate of ammonia and other valuable by-products are obtained from the tar and this helps to lower the operating cost.

The generator (1) is filled with fuel (3). Steam is generated under slight pressure in the boiler (1A), flows through pipe (6) and injects air coming through the air heater (1B) through pipe (5) into the bottom (2) of the generator (1).

Steam and air rise through the incandescent fuel in the generator; gas is produced and leaves the generator (1) through pipe (7). The warm gas passes through "down" pipe (8) and enters the bottom of the scrubber (10) filled with clean coke or charcoal (11).

Cold water enters the scrubber at the top and is sprayed over the coke, cooling and purifying the rising gas. Through pipe (12) the cool gas is conducted to the tar separator (13).

Occasionally a revolving tar separator is employed which frees the gas from the greater quantity of liquid tar by centrifugal force.

The gas now passes the drying and cleaning filter (14) filled with sawdust, and after passing another tar separator (15) enters the gas receiver (16) which, in large installations, is similar to the gas holders in illuminating gas works.

From the receiver (16) the gas is delivered to the gas engine or engines as required, under a slight and constant pressure.

It is to be noted that producer gas is always moist and contains more or less impurities such as soot, very fine dust, ash and tar—notwithstanding the precautions taken to clean it before it reaches the engine.

Where lignite is used as a fuel, it is not necessary to introduce steam into the generator, the lignite containing sufficient moisture. The air is then blown into the generator by means of a centrifugal blower.

METHODS OF LUBRICATION

Internal Lubrication (Figs. 4 and 9)

The cylinder (A), stuffing boxes (A2) and exhaust valve spindles (H1) are always lubricated by means of a mechanically operated lubricator (O) delivering the oil under pressure to the various parts.

The feeds of the lubricator (O), once adjusted, require no further attention. One filling of the mechanically operated lubricator lasts a long time.

The lubricator (O) is operated from the cam shaft. A cam actuates an oscillating lever which gives motion to the internal mechanism in the oiler, so that pump plungers automatically pump oil through the feed pipes.

In order to insure that the oil pipes are always full they should be provided at the extreme ends with spring loaded check valves. A spring loaded check valve is a non-return valve kept closed by a spring. When the lubricator is working, the pressure on the oil in the oil pipes forces open the check valve and the oil is delivered to the respective points.

When the engine is stopped and the lubricator ceases to operate, the check valve prevents the oil from running out of the pipes. The pipes are thus constantly kept full of oil, and instant lubrication is assured whenever the engine and lubricator start to operate.

Cylinder (Figs. 4 and 9)

The oil is introduced into the cylinder at from three to six points, through pipes (O3) from the mechanically operated lubricator (O). The oil inlets are sometimes located at the middle of the cylinder of four-stroke cycle engines, but in the case of two-stroke cycle engines this is not possible, as the exhaust gases pass out through the ports (H1) into the exhaust belt (H4) around the middle of the cylinder. In this case the oil inlets are placed about half-way between the exhaust belt and the cylinder ends.

It is important that the oil be introduced into the cylinder at the moment when it will be fed directly to the piston and piston rings. If introduced when the oil inlets are uncovered, the oil would be burned by the hot gases with resultant waste of oil and the formation of deposits.

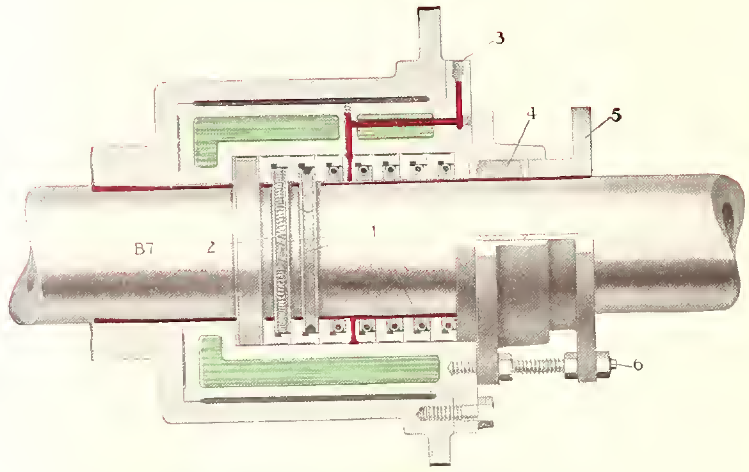


FIG. 8. Stuffing Box

Stuffing Boxes (Figs. 4 and 9)

The stuffing boxes (A2) located in the cylinder heads (A1) are the parts of the gas engine which usually give the most trouble.

The oil is introduced under pressure into the middle of the stuffing box (Fig. 8), being admitted through the oil hole (3) and distributed over the entire frictional surfaces of the packing rings (1).

Eight cast-iron packing rings (1), made in two halves, are shown, held together around the piston rod by means of light garter springs (2). These packing rings prevent the exploding gases from escaping past the stuffing box, provided the oil film is complete.

Outside the packing rings there is occasionally a second stuffing box, employing soft packing (4), this being compressed by means of a gland (5) held in position with studs (6).

Exhaust-Valve Spindles (Fig. 9)

Although the exhaust-valve guides (H3) surrounding the exhaust-valve spindles (H7) are water cooled, it becomes necessary to lubricate the spindles with a uniform and very sparing supply of oil through oil pipe (O1) from the mechanically operated lubricator (O).

Irregular or excessive oil feed produces carbon deposit, which causes the exhaust-valve spindles (H7) to stick.

With an excessive oil feed the excess oil burns and carbonizes.

With too sparing a supply of oil, too little lubrication is provided. The spindle becomes overheated and carbonizes the oil fed to it.

In either case the exhaust-valve spindle is inclined to stick.

Mixing and Inlet Valves (Figs. 4 and 9)

The spindles of the mixing and inlet valves (H2) and (H), respectively, are sparingly hand oiled, except in very large engines, where they

are supplied with oil through separate feeds from the mechanically operated lubricator (O).

Gas and Air Pumps (Fig. 4)

As the gas and air are sucked into these pumps at a slight vacuum and delivered from the pumps to the working cylinders at a pressure of 4 to 6 pounds, the temperature of the pump cylinder walls, due to compression, is not much above 100° F. There is, therefore, no need for water-jacketing these cylinders, and lubrication presents no difficulties where the gas and air are clean.

The practice has been to feed the oil through sight-feed drop oilers (S) into the center of each pump cylinder, with additional oil feeds to either end of both gas and air valve chambers.

Frequently, however, an accumulation of deposits has been experienced, due to moist, dirty gas and overfeeding of the oil, the impurities adhering to the excess oil.

External Lubrication (Fig. 9)

Circulation System

In the external lubrication of large gas engines a circulation system is usually employed. The lubrication of the main bearings (not shown)—crank pin (E), cross-head (D), tail-rod support (D3) and guides (D1)—is accomplished by means of oil fed by gravity from the top supply tank (T), through the distributing pipe (T1), and its branches, into the various bearings. Adjusting valves are fitted in the branch pipes to regulate the oil feeds. Having done its work, the oil drains back, through pipes (T2), to the bottom receiving tank (T3).

The oil pump (T4) driven by the engine draws the oil from the receiving tank (T3) and delivers it through the oil cooler (T6) and pipe (T5) into the top tank (T). If more oil is delivered to the top tank (T) than is required for the bearings, the surplus oil overflows through the pipe (T7) into the receiving tank (T3).

The top tank (T) may be omitted and the oil pumped directly from the oil cooler (T6) into the distributing pipe (T1), in which case it becomes necessary to have a relief valve, through which the surplus oil is passed back into the tank (T3).

Timing Shafts (G) are supported by ring oiled bearings (G2).

Eccentrics (G1) are equipped with sight-feed drop oilers or automatic spring grease cups.

Valve Levers are sparingly hand oiled.

Governor (not shown)—The governor is oiled partly by sight-feed drop oilers and partly by hand.

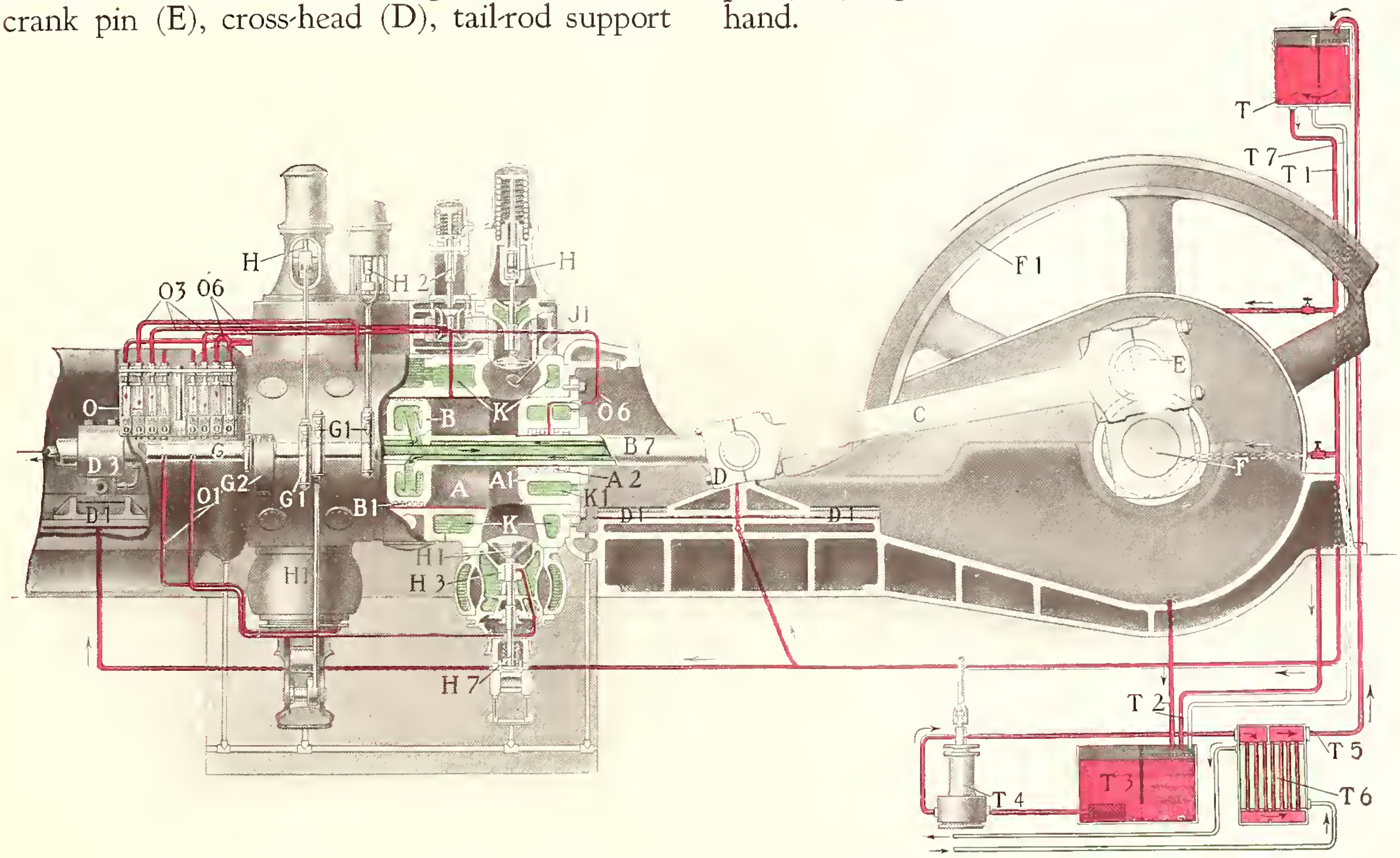


Fig. 9. Sectional View of One Cylinder of a Tandem, Four-stroke Cycle, Double Acting Gas Engine

OIL

Internal Lubrication

Only by the proper application of high-grade oils, especially manufactured, will the engines continue to operate at their highest efficiency, with a minimum cost of renewals and repairs.

If an oil of *too heavy* body is used, the oil does not easily spread over the piston surface and the friction is high, owing to the heavy oil drag on the piston. Such an oil is also likely to lead to excessive formation of carbon deposits, developed not only by decomposition of the oil itself, but also because it will absorb and hold impurities introduced with the gas and air. Such impurities cling to the heavy oil and bake into crust-like deposits.

If an oil of *too light* body is used, it will, notwithstanding a liberal oil feed, break down under the influence of high temperature in the cylinder, losing its sealing power and causing excessive wear of the piston, piston rings and cylinder walls. Deposits are formed, containing a large percentage of iron and iron oxides, due to the wear of the cast-iron piston, piston rings and cylinder.

Such an oil allows the gases, after explosion, to escape through the stuffing boxes; the gases burn and char the oil, causing heavy wear and the formation of deposits, shortening the life of the metallic packing. The gases which escape from the stuffing boxes into the engine room are very poisonous.

External Lubrication

The circulation system, whether operated by gravity feed from an elevated tank or by direct pump pressure feed distribution, should contain not less than two to three barrels of oil, in order to give the oil a chance to rest and separate from the impurities that may enter the system.

The oil is in constant circulation and in contact with air and more or less water which leaks in from the cooling system employed.

In passing through the main bearings and crank-pin bearings, the oil is subjected to great bearing pressure and speed of the rubbing surfaces.

As a result, when an unsuitable oil is used, it darkens in color, increases in viscosity and gravity, and develops considerable acidity, due to oxidation.

The oil may even throw down deposits of various kinds, possibly due to its improper manufacture; and such deposits are liable to accumulate in the most dangerous places, namely, the oil passages inside the main bearings and crank pin. The oil feed will thus be reduced, the bearings will heat up, and the bearing surfaces may be partly or wholly destroyed. The use of an unsuitable oil means uncertainty of operation and high cost of renewals and repairs.

With an unsuitable grade of oil the bearing temperatures are always high, which increases the rate of oxidation, so that frequently the life of an ordinary oil is very short.

Where emulsification takes place, due to the presence of water, the quantity of oil in circulation is reduced, so that the strain on the remaining oil is considerably increased.

High-grade Oil

High-grade oil, especially manufactured for use in circulation systems, will give excellent results during long periods of service.

Its superior separating qualities render it least liable to develop dangerous deposits.

Its excellent lubricating value results in the maintenance of reasonably low bearing temperatures and assures certainty of operation.

Water Leakage

Leakage of water into the oil system is a source of great annoyance and produces emulsion, particularly where ordinary oil is used. The life of the oil is much reduced; the bearing temperatures run high; wear of crank pins and cross-head pins follows immediately.

It is almost impossible to keep all water out of the system, but leakage may be largely overcome by careful and constant attention to packing and joints of the cooling water inlet and outlet pipes, and by a system of daily treatment of the oil.

Daily Treatment of the Oil

In view of the unfavorable influence of water in the circulation system, any accumulation of water and impurities should be carefully drained away at frequent intervals.

Where a great many impurities enter the system, it is good practice to *remove from two to six gallons of oil every day for treatment* in a steam-heated separating tank, and afterwards in a good filter. The purified oil should be returned to the circulation system at the same time that a corresponding quantity of oil is removed from the system for treatment.

When the oil tank capacity in the system is small, this practice is particularly desirable. In this way the vitality of the oil is kept at as high a standard as possible, and the life of the oil is greatly lengthened.

DEPOSITS

Deposits are generally, not always correctly, termed carbon deposits.

Deposits may arise from one or several of the following causes: dust or dirt in the intake air; impurities in the gas; over-feeding of oil; the use of an unsuitable oil.

The formation of deposits under certain conditions leads to preignition and backfiring. (See section below.)

Deposits form in the mixing and inlet valves, in the cylinders, on the two sides of the piston, behind and between the piston rings, on the exhaust valves, and in the stuffing boxes. In two-stroke cycle engines deposits are also formed in the gas and air pumps and in the exhaust ports.

Impurities in the Air

Impure air is a frequent cause of deposits in large gas engines, regardless of the kind of gas used. When deposits arise from this cause, a chemical examination will reveal the presence of fine sand, iron ore dust, lime dust, etc.

The air should be filtered through coarse canvas or similar material before passing to a large settling chamber, which will collect more of the solid impurities.

Impurities in the Gas

Coke oven gas and pressure producer gas made from bituminous coal contain sulphur, which forms sulphurous acid, the presence of which causes blackening of the frictional surfaces. For example, brownish-black patches will be observed on the piston rod.

If the gas is moist, fine dust is deposited in the mixing valves and inlet valves, in the form of black paste.

In two-stroke cycle gas engines, moist gas will deposit dust, in the form of a dark sludge, in the valve chamber of the gas pump.

The sludge causes increased resistance in moving this valve with consequent sluggish action of the governor.

Where deposits are due to impurities in the gas, a chemical examination will prove the presence of lime dust, volatile matter, water impurities, iron oxides, etc.

Deposits arising from air or gas, or both, always contain oil and also partly decomposed oil, the latter due to action of the impurities on the oil under high temperature conditions.

Over-feeding of Oil

The surplus oil, fed to the internal parts, burns and chars; it also attracts and collects the impurities from the gas and air, resulting in a dark colored carbonaceous deposit of a harder or softer nature, depending upon the quality of the oil in use.

Even with a high-quality oil in use, *the oil feed should be reduced* to the exact amount required for full and efficient lubrication. This will lead to clean lubrication, as the impurities find less oil to which they can adhere.

Frequently the *stuffing boxes are over-lubricated,* with the result that carbon deposits are formed, causing the packing rings to stick in their grooves. Wear follows and the exploding gases blow past the rings.

Deposits accumulating behind the piston rings may cement the rings in their grooves, indicated by the piston groaning. Heavy wear takes place; the oil film is burned away; the burning gases pass from one side of the piston to the other, igniting the fuel charge on the opposite side and causing preignition.

Increased oil feed will only aggravate this trouble.

Unsuitable Oil

An unsuitable or low-quality oil *must* be used in excess. It burns and chars freely, producing a greater amount of carbon than the correct, high-grade oil. The formation of carbonaceous deposits is aggravated by the impurities in the gas or air.

Preignition and Backfiring

Where deposits develop on the two sides of the piston and inside the cylinder or in the valve chambers, they often become incandescent (particularly if the water cooling is inefficient) and fire the fuel charge before ignition ordinarily would take place. This is called preignition.

The explosion against the advancing piston causes abnormally heavy strains on the engine, sometimes resulting in serious damage.

With blast furnace gas it is difficult to prevent preignition, owing to the quantity of fine lime dust in the gas which, when it settles inside the cylinders, easily becomes incandescent.

Preignition explosions can always be distinguished from ordinary explosions, as they are much louder and sharper.

Sometimes the fuel charge does not fire in the engine, owing to momentary failure of the electric spark or because the mixture of gas and air is too weak to explode. In these cases the unburned fuel charge is passed out of the engine into the exhaust pipe where, on coming in contact with the hot gases from previous explosions, the fuel charge will explode with a banging noise.

These explosions are called exhaust explosions or backfiring.